RESEARCH HIGHLIGHTS

Technical Series 99-107 Rev.

DRYING OF STUCCO-CLAD WALLS

Introduction

In recent years, some low-rise, multi-unit, wood-frame residential buildings in the coastal climate of British Columbia have experienced building envelope performance problems including water penetration, damage to cladding systems and decay of wood components. The CMHC research report *Study of Building Envelope Failures in the Coastal Climate of British Columbia* linked the cause of the deterioration problem to rainwater penetration into the stud cavities of the wall assemblies, especially at construction details.

The effective performance of exterior wall systems, especially in the coastal climate of BC, is dependent on the ability of the wall assembly to limit the wetting of moisture-sensitive wall components (especially in the stud cavity) and to allow the assembly to dry out should these components become wetted.

Relying primarily on the outer most cladding, face-sealed systems provide little or no moisture management strategy to remove or dissipate moisture once it penetrates past this exterior protection through cracks, joints, openings and penetrations. Alternatively, Rainscreen walls, as well as other variations of drained wall cavity designs vented to the exterior, provide an ability to manage moisture and limit the wetting potential by providing a capillary break between the porous exterior cladding and the underlying materials. In addition, proprietary products such as geotextiles, used primarily to drain moisture below grade, and other drainage fabric materials introduced into the marketplace have also been incorporated into exterior wall designs, immediately behind exterior claddings, to provide a drainage medium by which to remove, from the wall assembly, moisture penetrating through the cladding material.

Improved wall detailing and execution at penetrations will undoubtedly reduce the risk of water entering, but will not eliminate it. Even if no exterior moisture gets into a wall, high initial construction moisture in the wood components and plumbing leaks and spills, however rare, from inside the building may lead to conditions which could promote wood deterioration and corrosion of metal components.

Walls must be allowed to dry, but it was unknown if a drainage cavity behind stucco cladding had any effect on the drying potential of stucco-clad walls. An experiment to answer this question was undertaken.

Funding, financial or in-kind services for this project was provided by a number of interested parties including the National Research Council (IRAP), Van Maren Construction Group, Centreville Construction Ltd., British Columbia Housing Management Commission, City of Vancouver, Seymour Building Systems and Canada Mortgage and Housing Corporation. The experiment was designed and executed by Morrison Hershfield Limited.

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The experiment consisted of wetting the stud cavities of seven differently designed stucco-clad wall test specimens and observing their drying. Five specimens were constructed with wood framing and two with steel framing. All were 1220 x 2440 mm (4'-0" x 8'-0") in size, with studs at 406 mm (16 inches) centres.

All specimens were constructed with the following layers:

1. 12 mm Gypsum Board, installed airtight;
2. 0.25 mm (10 mil) polyethylene film vapour barrier;
3. 38 x 89 mm wood studs or 92 mm steel studs with R-12 glass fibre batt insulation;
4. 12 mm plywood sheathing on wood studs or 12 mm Dens-Glass Gold® gypsum sheathing on steel studs, installed horizontally with a 3 mm gap between sheets;
5. 60 minute building paper, shingle lapped;
6. Drainage cavity (various designs as described below), vented and flashed top and bottom;
7. 19 mm sand-cement stucco, cured for 28 days.

One of the wood-frame specimens had stucco applied directly, without an air space. All the others incorporated one of the following methods to ventilate and drain the cavity space behind the stucco:

- 19 mm vertical wood strapping at 205 mm centres, with a layer of 30 minute building paper over it to keep stucco out of the cavity;
- 9.5 mm Hydroduct without fabric backing on both steel stud and wood stud;
- J-Drain (type and size not specified) also without fabric, with a layer of 30 minute building paper over it to keep stucco out of the cavity;
- 9.5 mm vertical wood strapping at 205 mm centres, with a layer of 30 minute building paper over it to keep stucco out of the cavity;
- 19 mm vertical galvanized sheet metal Z-bars on steel stud.

The bottom was flashed with a drip flashing, extending from the face of the sheathing (behind the building paper) to the face of the stucco, with a 12 mm gap between it and the bottom edge of the stucco. At the top of the wall, a metal flashing covered the top edge of the stucco, with a 6 mm gap between the back of the flashing and the face of the stucco, and with a 12 mm gap above the top edge of the stucco under the flashing.

Each specimen was provided with sensors to measure moisture content of wood framing and moisture content of both wood and gypsum sheathing. Sensors were installed in the interior studs at 50 mm and 600 mm above the bottom plate, in the sheathing along the vertical centre of the panel, in the bottom plate at the centre of the panel, and at the centre of one adjoining stud space at the 50 mm and 600 mm heights. Temperature and relative humidity sensors were placed 300 mm above the bottom plate, at mid-height of the specimen (middle stud space), on the bottom plate and 150 mm below the top plate (center stud space). Preliminary tests with additional specimens and more instrumentation had been done to determine what types of sensors to use, and where. The moisture content readings for the gypsum sheathing are the actual meter readings and were not correlated with actual moisture content of gypsum. The wood moisture content values are also the actual meter readings and were not corrected for temperature or wood species.

Water injection tubes were fitted into the top of each wall specimen to control the quantity and rate of water introduced into the insulated stud space. A waterproofing membrane sealed the bottom of the specimen bottom plate to prevent leakage out at the base of the wall.

The completed specimens were fitted and sealed into openings in a refrigerated test chamber, with the stucco facing the cold side. Specimens were allowed to reach equilibrium, with no measurable changes of moisture content with time. After conditioning the specimens, water was introduced into the stud space of each specimen, evenly distributed against the inside of the sheathing at the top, at a rate of 1 litre per day for 4 days. For steel framed specimens, half as much water was used over the same time period.

The warm side was kept between 19°C and 25°C, with the relative humidity (RH) between 35% and 60%, while the cold side was between 5°C and 14°C, at 45% to 85% RH. There was no air pressure difference across the specimens and the effects of wind and solar heating, which might influence drying of building walls, were absent. After wetting the specimens, the test conditions were maintained and moisture data were recorded for 150 days before the experiment was terminated.

Results

After an initial peak between 80% and 90%, relative humidity of the air in the wall cavity at 600 mm above the bottom plate leveled off to 60% or 70% in a week (for wood) to a month (for steel), and declined slowly thereafter, never falling back to the initial level prior to introduction of water into the stud space. Drying was very slow, with no significant differences between specimens that had cavities and specimens without them. Introduction of the water had no evident effect on moisture content of studs at the 600 mm level. They remained at about 10% moisture content throughout. At 50 mm above the bottom plate the studs increased in moisture content gradually to about 20% in the first 30-40 days, after which they dried very slowly, never reaching the initial 10%. The effect on the sheathing at 600 mm was very similar, except that the peak occurred in fewer than 10 days. The wood sheathing at 50 mm increased rapidly in moisture content to exceed 80% in 2 to 25 days, and remained there in all cases for 75 days or more. Two specimens remained above that level at the end of the test. The other three dried to about 65%, 30%, and 25% respectively. The gypsum sheathing increased rapidly in moisture content in the first 10 days, one specimen reaching a reading of 40%, the other in excess of 80%, and then dried slowly. Both specimens reached about 12%, still in excess of the initial 10%, at the end of the test, after staying near their respective maximums for about 20 days.

When the walls were removed from the test facility and opened, dark staining was observed at the bottom of all wood wall panels, extending 150 mm up from the bottom plate. The water that had run down the sheathing had soaked into the wood at the bottom of the panels and was not redistributed by diffusion to other parts of the assembly to any significant extent. The steel framed specimens did not exhibit signs of deterioration from excessive moisture (only half as much water was introduced).

Implications for the Housing Industry

Effective water management strategies in exterior wall assemblies are important in the BC coastal climate. Walls that have cavities with drainage, venting, and appropriate detailing of penetrations are more effective at keeping rainwater out of stud cavities of walls than face-sealed walls without cavities. However, based solely on controlled thermal and vapour pressure differences to drive the drying process in the stud cavity, as undertaken in this research experiment, the following is concluded:

- neither the Rainscreen design nor the cavity drainage design experiences improved drying potential in the stud cavities compared to face-sealed stucco assemblies;
- once moisture enters the stud cavity, the drying process is very slow; and
- moisture movement or redistribution to other materials within the stud cavity is limited—where water enters a wall is where it stays. Water must not be permitted to enter into the stud cavity.

The report provides insights into design issues that require further research, including:

- a need to quantify the amount of water which can be managed by different cladding designs and by different drainage cavity designs;
- a need to develop design details which will be effective at eliminating water entry at envelope interfaces (i.e., wall penetrations, window penetrations, window/wall junctions, balcony rail/wall connections, deck/wall junctions, junctions between different wall claddings, etc.);
- evaluate whether improved drying performance of the stud cavities can be achieved through the effects of environmental factors such as solar radiation and wind (drainage cavity ventilation);
- assessing the constructability of designs; determining and assessing key factors such as the accessibility for construction, sequencing of trades and skill level of workers, etc.

CMHC Project Manager: Jacques Rousseau, Research Division

Research Report: *Drying of Walls with Ventilated Stucco Cladding: A Parametric Analysis*

Research Consultants: Morrison Hershfield Limited

A full report on this project is available from the Canadian Housing Information Centre at the address below.

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